NASA-CR-201423

Annual Performance Report
NASA-Ames Cooperative Agreement Number NCC 2-807

High Resolution Infrared Spectroscopy of Molecules of Terrestrial and Planetary Interest

For the period May 1, 1995 through April 30, 1996.

Submitted to
Dr. Charles Chackerian, Jr., Technical Officer
Atmospheric Physics Branch, 245-4
National Aeronautics and Space administration
Ames Research Center
Moffett Field, California 94035-1000

Prepared by

Dr. Christopher R. Mahon, Principal Investigator
Space Physics Research Institute
572 Hyannis Drive
Sunnyvale, California 94087-1315
(408) 736-9705

In the past year Dr. Christopher Mahon was hired as Principal Investigator in June 1995, replacing Dr. Mark Spencer who left SPRI early in 1995. Subsequent work has centered on two projects. The first, in June and July of 1995, was a study of the spectroscopy of the second harmonic of nitric oxide. The second project was the design and construction of a full sensitivity prototype spectrometer for the detection of atmospheric radicals at the part per trillion (ppt) level.

In the early part of 1995, as a result of a discussion with members of the Engineering Group at SRI International, a study was undertaken of the spectroscopy of the second harmonic of nitric oxide. No previous such study had been done, and the work addressed a specific problem SRI encountered in the design of a diode laser based trace nitric oxide detector. The Spectroscopy Group here at NASA Ames, with its high resolution BOMEN spectrometer and the 25 m White cell, is perfectly equipped to undertake this kind of study. In collaboration with Dr. Clint Carlisle, Dr. Haris Riris, and Dr. David Cooper of SRI, the spectral positions and linestrengths of the second overtone band were measured. The Spectroscopy group was involved only in data acquisition, and full data analysis and publication of the results is currently being done by the SRI group. The results have enabled the SRI group to resolve their detector problems, and to move forward with product development.

The remainder of the year has focused on the second project, to design and construct a full sensitivity prototype spectrometer, based on the Magnetic Rotation (MR) effect (G. Litfin *et al.* 1980), for the detection of atmospheric free radicals at the ~ppt level. This is phase two of the project, phase one being two years of feasibility studies (T. A. Blake *et al.* 1996). The proposed prototype spectrometer is comprised essentially of two components: a White cell, and the solenoid in which it is placed. Over the last year the final design specifications for these components were developed, and currently the instrument is being assembled. Full testing of the prototype will lead to the third phase, that of construction of an instrument to be deployed on airborne platforms.

The White cell was designed with the aid of commercial optical design software (refer to Fig. 1). The cell is made up of a pair of spherical mirrors between which a laser beam is reflected back and forth some predetermined number of times. The laser beam enters and exits through a single hole in one of the two mirrors. The design software was used to establish mirror parameters for optimum cell configuration, as well as the required alignment for the laser beam. The design was refined to 80 mm diameter mirrors, with radius of curvature of 400 mm, and mirror separation 426 mm. In this configuration, the laser beam passes 58 times between the mirrors, giving a total optical path of 25 m. With this choice of parameters the model calculations indicated the cell alignment to be robust, *i.e.*, that typically realizable laser beam entered and exited the cell unobstructed when small variations in optical alignment were introduced into the design program. With the optical characteristics of the cell determined, the gold coated mirrors were custom ordered, and tested to be in excellent agreement with the model calculations.

The White cell is to be positioned in the bore of the second major spectrometer component, the solenoid. The solenoid must provide the needed ~200 Gauss field, with reasonable power supply requirements, and in as compact a size as possible. At this point it is worth mentioning that instruments currently deployed on airborne platforms are greatly hindered by their payload requirements. The MR spectrometer promises to be much lighter, and so much attention has been paid to minimizing size and weight in the prototype. Extensive modeling of the relevant design parameters have been made using a commercial mathematical software. A typical, uniformly wound, wire solenoid has a factor of two variation of the magnetic field between the solenoid center and its ends. As a result a variable winding configuration has been adopted to provide as uniform a magnetic field over the entire solenoid length. With the winding density as a variable in the model calculations, a configuration was found that provided field uniformity to within 5% over 90% of the solenoid length. With the winding configuration determined, the physical and electrical characteristics of the solenoid were then modeled in order to determine the exact wire gauge required for winding. The final design optimizes solenoid size, weight, breakdown voltage, a.c. operating frequency, field uniformity, and power supply requirement.

Based on the model results a test solenoid was constructed, and tested in d.c. operating mode for field uniformity. In Fig. 2 is shown the measured axial magnetic field as a function of the position along the length of the solenoid. Also shown for comparison is the model prediction, as well as the field of a uniformly wound solenoid. Agreement with the model is excellent. It was discovered in testing that the enamel coated magnetic wire of the test unit are not sufficiently insulated to prevent voltage breakdown at the ~1000 V voltages that exist between layer windings when the solenoid is operated in a.c. mode at the full ~200 Gauss peak fields. Tests at lower (~10 Gauss) a.c. fields, however, indicate that the winding configuration works as expected from the model calculations. Having verified the basic design, a fully insulated working solenoid is currently under construction.

An important consideration in the spectrometer design is the material used in assembly. For measuring ~ppt level radical molecules it is crucial that the walls of the White cell be non porous to the molecule to be measured, otherwise background signal will be introduced from molecules desorbed from the cell walls. A second criterion is that all spectrometer materials must be both non magnetic, and non metallic. Magnetic materials clearly perturb the fields used for the MR effect, while metallic materials, by the creation of eddy currents when placed in an a.c. magnetic field, will also modify the fields in the spectrometer. For these reasons the spectrometer has been designed to be of quartz and TFE Teflon. These pieces are currently being fabricated.

The spectrometer design has been presented at the NASA Ames DDF Poster session in November 1995, and at the March 1996 meeting of the Optical Society of America. Abstracts for these posters are included.

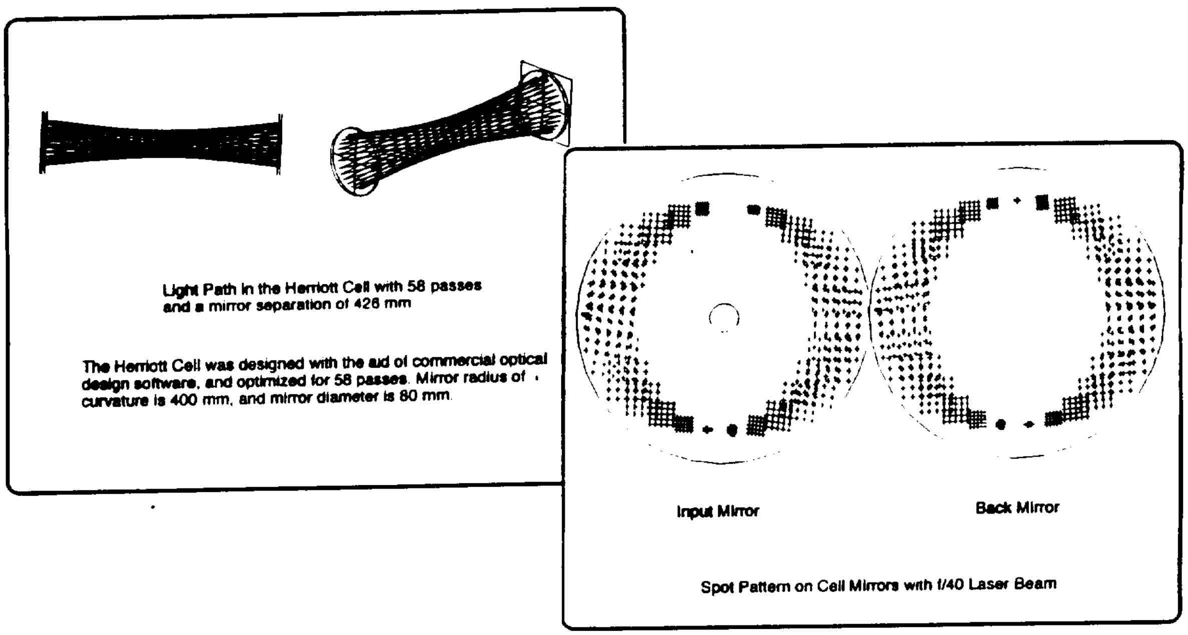

Fig. 1

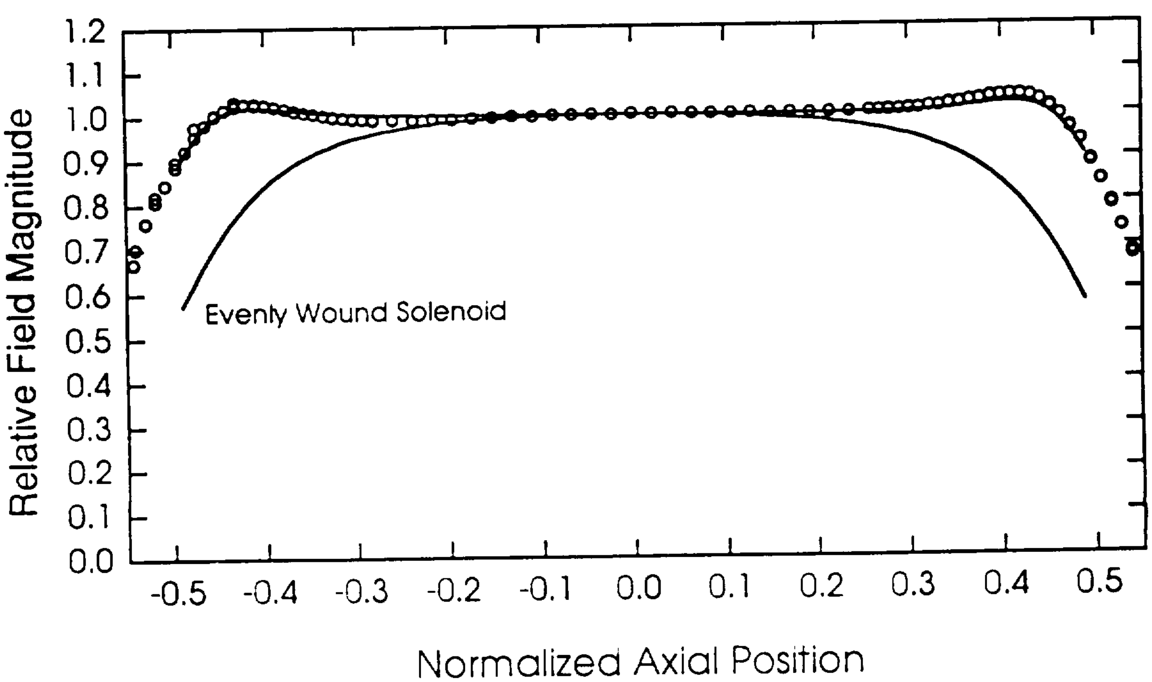

Fig. 2

References

Thomas A. Blake, Charles Chackerian, Jr., and James R. Podolske 1996, *Applied Optics* **35**, 973-985.

G. Litfin, C. R. Pollock, R. F. Curl, Jr., and F. K. Tittel 1980, "Sensitivity enhancement of laser absorption spectroscopy by magnetic rotation effect," *J. Chem. Phys.* **72**, 6602-6605.